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Construction Engineering Research Laboratory

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Retrofit Options

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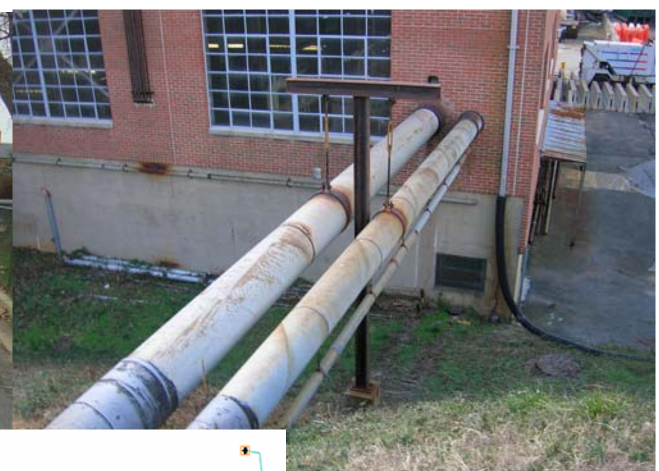
December 2006



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Final Report

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Abstract: Many of the buildings on Fort Myer, VA are over 50 years old and are serviced by systems and utilities that have been modified and upgraded over the years. The system distribution and central steam heating system is one such system that is now nearing the end its useful life. This study was undertaken to identify the most cost effective solution to provide heat to the Fort Myer's buildings in the future years, whether to: (1) maintain the existing system, (2) convert to a centralized system using hot water, or (3) convert to a decentralized system. An evaluation of the three alternatives showed that a hot water heating conversion will provide the lowest life cycle cost and allow the most fuel flexibility. Fort Myer also manages installation support for Henderson Hall, an adjacent Marine base. This study analyzed two heating options for Henderson Hall: (1) connecting Henderson Hall buildings to the new hot water distribution system proposed to serve Fort Myer, or (2) using the existing steam heating plant in Building 28 to heat the five Henderson Hall buildings. A life cycle cost analysis shows that the expansion of the hot water system is the most cost effective choice.

Executive Summary

Fort Myer is a U.S. Army installation located in northern Virginia a few miles from the Pentagon, the primary function of which is to provide support to the National Capital Region and housing to senior Army officers. Many of the buildings on the installation are over 50 years old and are serviced by systems and utilities that have been modified and upgraded over the years. The system distribution and central steam heating system is one such system that is now nearing the end its useful life.

Fort Myer's central steam heating system is housed in Building 447, which contains three boilers, all in good working condition. Other parts of the system are difficult to maintain and use excessive energy. The underground steam/condensate distribution is prone to failure, resulting in leaks that waste both energy and treated water, at an annual cost approaching $250,000. These leaks are difficult to find and expensive to repair. In the past 2 years, approximately $300,000 has been spent repairing these lines. Additionally, the use of steam as a heating medium is hard to control. It is supplied at a constant pressure and temperature so its use is controlled by adjusting the flow rate. This practice often leads to overheated buildings and consequent energy waste. Many buildings surveyed were found to have temperatures over 80 °F, an energy waste that translates into a cost of at least $50,000 per year.

The objective of this study was to identify the most cost effective solution to provide heat to the Fort Myer's buildings in the future years. The solution must provide comfort to building occupants, be easy to operate, require minimum maintenance, significantly reduce energy waste, and have a reasonable installation cost. Three heating scenarios are evaluated for application to Fort Myer:

1. *Maintain the Status Quo:* Continue to repair and update the existing system with no change in operation. This scenario includes a continued degeneration of the system and an increase in the number of system failures.
2. *Convert to a Centralized System Using Hot Water:* Convert the central system to an underground distributed hot water heating system.
3. *Convert to a Decentralized System:* Replace the central system with distributed heating equipment installed in each building.

The continued use of the existing heating system has an estimated annual energy cost of $982,000. After adding the estimated maintenance cost of $206,000 and the make-up water cost of $78,000, the annual cost of this system is $1,266,000.

The steam to hot water heating conversion requires new distribution piping, replacement of the building interfaces and refurbishment of the entire control system. A new piping system for the supply hot water must be installed since the existing condensate return piping is worn out, and in any case, is too small to handle the required hot water flows. The new underground piping system will be insulated with foam and covered with a PVC jacket. Embedded in the foam is a sensitive leak detection wire that will enable Fort Myer staff to quickly find leaks: (1) without exploratory digging, and (2) before catastrophic failure or chronic water loss. The new pipes will be used as the hot water supply pipes and the existing steam pipes will be the return water pipes. The cost for the new piping system is approximately $1,750,000.

At each building, there needs to be a hot water to hot water heat exchanger installed to replace the steam heat exchanger. In the central power house, Building 447, heat exchangers to transfer energy from the steam to hot water are also required. New pumps to circulate the hot water to the buildings will be added. New controls will be added to adjust the water temperature lower during mild weather conditions. The lowering of the hot water temperatures will reduce heat losses in the distribution system and helps to control building overheating. The estimated cost of this equipment is $1,609,000 for a total system cost of $3,359,000.

The annual operating cost of this system is estimated to be $732,000. There is an energy cost savings of $327,000 due to less heat losses and better control of building temperatures. There is a small electrical energy cost saving since the condensate return pumps savings is offset by the electrical use of the circulating pumps. The maintenance costs and water are estimated to be $76,000 per year.

The distributed heating system requires a new heating boiler and hot water generator for each building. A small building addition is required for this modification. The estimated cost of this equipment is $3,954,000. The current natural gas underground piping would need to be increased in size to handle the addition gas use. The cost to upgrade the natural gas underground is $820,000, for a total cost of $4,774,000.

Distributed heating systems provide annual energy savings compared to central systems, but the central systems have the advantage of using multiple fuels so if one fuel type becomes expensive the plant can switch to another. The energy cost of operating this system is $494,000 per year. When maintenance costs are added, the total annual cost is $607,000.

Table ES1 summarizes the results of the evaluation of the three alternatives for heating the majority of buildings at Fort Myer. The hot water heating conversion will provide the lowest life cycle cost. This alternative also allows the most flexibility in choosing the fuels of the future for this installation. With a central system, equipment can be more readily installed to consume a wide variety of fuels. If special treatment is required for emission control, fuel handling, or containment, it can be most effectively done at one location rather than at the multiple sites required by a distributed system.

Due to the decisions in BRAC 2005, Fort Myer is now required to manage installation support for Henderson Hall, an adjacent Marine base. This study will analyze the heating options for Henderson Hall, which is currently heated by the boiler plant at the Pentagon. Steam is generated by this plant and distributed to Henderson Hall using the Naval Annex piping as a means for transporting the steam to these buildings. The Naval Annex is scheduled for demolition in a couple years and another source of heat will be needed. There are two options to satisfy this heating requirement:

1. Connecting Henderson Hall buildings to the new hot water distribution system proposed to serve Fort Myer
2. Using the existing steam heating plant in Building 28 to heat the five Henderson Hall buildings.

Table ES1. Cost comparison of Fort Myer heating options.

District Heat Option	Installation Costs	Estimated Energy Cost	Estimated Annual Cost	Simple Payback	SIR
Base Situation, Existing Steam Heat	$ —	$982,000	$1,266,000	N/A	
Hot Water Distributed Heat	$3,359,000	$655,000	$732,000	6.3 yr	
Distributed heating Systems	$4,774,000	$494,000	$607,000	7.2 yr	

The life cycle costs of these two options will be compared to the combined costs of using the Henderson Hall boilers and the existing steam plant at Fort Myer (the base case). The Henderson Hall steam heating system will use the existing boilers installed in Building 28. The systems in this building will need to be recommissioned. A new third boiler of a similar size will need to be installed. The estimated cost to make this boiler plant operable is $164,000. The Henderson Hall will be able to burn only natural gas, thereby losing flexibility to burn alternative fuels. The annual operating cost of this system is estimated to be $1,628,000.

Adding the five Henderson Hall buildings to the Fort Myer proposed hot water distribution system drawings will increase the cost of that system by almost $1,000,000 for a total installed cost of $4,337,000. The addition of these building will require a new pipe to these buildings.

Table ES2 lists the associated costs for these alternatives. The life cycle cost analysis shows that the expansion of the hot water system is the most cost effective choice.

The application of a co-generation system was proposed for evaluation; unfortunately the summertime heating requirement at Fort Myer is so low only a small diesel powered generation unit would be needed to satisfy the heating demand. The electrical power this unit would generate is approximately 200 kW, which would have no impact on the Post's electrical costs.

The application of district hot water heating was also considered for Fort McNair. It was concluded that such a change is worth considering when the current system needs replacement. The current steam heating equipment is in good condition and fairly energy efficient. The buildings are close together, limiting distribution losses.

Table ES2. Cost comparison of Fort Myer and Henderson Hall heating options.

District Heat Option	Installation Costs	Estimated Energy Cost	Estimated Annual Cost	Simple Payback	SIR
Base Situation - Existing Steam Fort Myer & Henderson Hall	$164,000	$1,241,000	$1,628,000	N/A	
Hot Water Distributed Heat	$4,337,000	$841,000	$921,000	6.1 yrs	
Hot Water Heating Fort Myer & Steam Heating Henderson Hall	$3,569,000	$913,000	$1,090,000	6.6 yrs	

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Preface

This work was done for Fort Myer, VA, under Project Requisition No. 127396, Activity A1020, “Annex 46 Holistic Assessment Toolkit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo),” via Military Interdepartmental Purchase Request (MIPR) 6CCERB1011. The technical monitors were Mark Zangara, Directorate of Public Works (DPW), Fort Myer, and Paul Volkman, Headquarters, Installation Management Agency (HQ-IMA).

The work was managed and executed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The CERL principal investigators were Dr. Alexander Zhivov and John L. Vavrin. Stephen Richter is associated with GEF Ingenieur AG, Germany; Norbert Paetz is associated with MVV Energie, Germany; and Alfred Woody is associated with Ventilation/Energy Applications PLLC, Rochester Hills, MI. Dr. Thomas Hartranft is Chief, CEERD-CF-E, and Mr. L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Paul A. Howdyshell CEERD-CV-T. The Director of ERDC-CERL is Dr. Ilker R. Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
British thermal units (International Table)	1,055.056	joules
cubic feet	0.02831685	cubic meters
cubic inches	1.6387064 E-05	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
fathoms	1.8288	meters
feet	0.3048	meters
gallons (U.S. liquid)	3.785412 E-03	cubic meters
horsepower (550 foot-pounds force per second)	745.6999	watts
inches	0.0254	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
mils	0.0254	millimeters
ounces (mass)	0.02834952	kilograms
ounces (U.S. fluid)	2.957353 E-05	cubic meters
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per cubic inch	2.757990 E+04	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
quarts (U.S. liquid)	9.463529 E-04	cubic meters
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

1 Introduction

1.1 Background

The Fort Myer Military Community (FMMC) includes Fort Myer (located in Arlington, VA) and Fort McNair (located in Washington DC). The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) was tasked with evaluating the heating systems at these Army installations and making recommendations for their future operation.

The heating system at Fort Meyer consists of two central boiler plants and individual building heating systems. The installation's two central boiler plants are located in Buildings 447 and 311. The heating system in Building 447 is the largest serving 46 buildings. The boiler plant in Building 311 provides heat to four buildings in the DPW area of the installation.

Researchers focused on the larger heating plant (in Building 447) and performed a life cycle cost comparison to evaluate three options for the heating systems at Fort Meyer, whether to: (1) continue to produce steam for distribution (the "base case"), (2) switch to a hot water distribution system (hot water central system), or (3) abandon the central plant at Building 447 and install individual building heating systems (a "distributed system"). Appendix A to this report contains the detailed life cycle cost calculations.

Additionally, this investigation evaluated alternatives for heating Henderson Hall, an adjacent military installation that Fort Myer will eventually be required to maintain under the Base Realignment and Closure (BRAC) 2005 decision. Henderson Hall is currently heated using steam boilers located in the Pentagon complex, but that service will end shortly due to the demolition of facilities that contain the steam line from the Pentagon to Henderson Hall. Consequently, Henderson Hall will need to be heated either by systems from Fort Myer (using the central plant in Building 447) or by operating a small standalone plant within the Henderson Hall complex. This study also performed a life cycle cost comparison of these two options.

Fort McNair is currently served by a central steam heating system, which is in good condition. Since there are no significant maintenance problems

with this system and the building served are very close together no feasible economic alternatives were identified.

1.2 Objectives

The objectives of this study were to:

1. Evaluate the performance of the heating system develop retrofit options
2. Conduct a technical and economic analysis of the heating systems
3. On the basis of a life cycle cost comparison, recommend whether the installation should:
   a. continue to produce steam for distribution (base case),
   b. switch to a hot water distribution system (hot water central system), or
   c. abandon the central plant at 447 and install individual building heating systems (a distributed system).
4. Provide options for improving the larger central boiler plant (in Building 447).

1.3 Approach

Analysis of the steam heating system at Fort Meyer was conducted as a pilot project to implement lessons learned from the study "Evaluation of European District Heating Systems for Application to Army Installations in the United States."

Field studies and analyses of existing heating systems at Fort Meyer, Henderson Hall, and Fort McNair done by the CERL team in collaboration with a private sector parties were followed by technical and economical evaluation of retrofit options.

1.4 Mode of Technology Transfer

The results of this study will be provided directly to the project sponsors. This report will be made accessible through the World Wide Web (WWW) through URL:

http://www.cecer.army.mil

2 Existing Condition

The buildings at Fort Meyer consists of a number of single family housing units, barracks, dining facilities, administrative buildings, various support facilities, and buildings used for ceremonial functions. A central boiler plant provides heat to 46 of these buildings (Table 1). A small boiler plant in Building 311 provides heat for four additional buildings. The rest of the buildings are heated by individual heating system.

The central boiler plant in Building 447 has four boilers installed, of which three are operational (Figure 1). The largest boiler, rated at 1200 boiler horsepower (40,000 MBH) is normally operated only during the heating season. The other two smaller boilers, each rated at 600 boiler horsepower (20,000 MBH), are used year-round. The inoperable boiler has a capacity of 12,000 horsepower and has not been used for years. All operable boilers are capable of firing both natural gas and fuel oil. Fuel oil is used when natural gas is not available at the interruptible rate. Steam at 90 psig is distributed underground to the buildings served. There is also an underground return piping system used to return condensate water. The steam generated provides for building heat, heat for domestic hot water, steam for clothes pressing machines (in 10 buildings), and steam for dining facility cooking/washing operations.

Table 1. Buildings served with steam from Building 447.

Building No.	Building Function	Building Area (sq ft)	Building Occupancy (No.)	Heating Load (BTUH)	Building Heating Load (BTUh/sq ft)
11	Quarters	11,228	10	427,214	38
12	Quarters	11,228	10	428,297	38
13	Quarters	8,832	10	328,177	37
14	House	8,833	10	328,096	37
15	Quarters	11,228	10	428,151	38
16	Quarters	11,229	10	428,297	38
19	Quarters	7,187	10	322,729	45
20	Quarters	7,187	10	322,729	45
21	Quarters	7,188	10	322,729	45
22	Quarters	7,189	10	322,729	45
23	Quarters	7,425	10	329,155	44
24	House	10,278	10	418,412	41

Building No.	Building Function	Building Area (sq ft)	Building Occupancy (No.)	Heating Load (BTUH)	Building Heating Load (BTUh/sq ft)
25	House	10,278	10	418,412	41
26	House	10,279	10	418,412	41
27	House	8,750	10	368,929	42
59	Installation HQs	21,423		799,041	37
224	Thrift Shop	7,119		465,339	65
237	Fire Dept.	5,150		240,248	47
238	Cadet Office	4,540		262,040	58
241	Ceremonial Hall	38,652		1,215,764	31
242	Old Guard HQ	17,488		573,122	33
243	Town Hall	4,388	5	257,976	59
246	Company Quarters	68,700	203	2,224,995	32
248	B&D Company Quarters	69,000	179	2,232,535	32
249	3rd Infantrz Museum	32,000	83	1,010,397	32
250	HQ Honor Guard	27,500	74	888,699	32
251	Barracks	29,487	84	919,714	31
400	Band Training	57,973		1,557,563	27
402	"H" Company Barracks	110,000	275	3,034,198	28
403	Barracks	166,250	650	4,503,075	27
404	Tri-Service Dining	32,580		1,346,904	41
405	Community Center	15,700	260	686,750	44
406	Barracks	166,250	650	4,469,980	27
407	NCO Club	21,450		883,001	41
410	MP Company Barracks	32,000	125	1,006,910	31
411	Bowling Center	18,600		763,180	41
414	Fitness Center	37,000	93	2,818,820	76
416	HQ Company Barracks	49,600	125	1,811,185	37
450	PX Building	41,858		1,639,536	39
469	Child Development Center	38,865		2,169,022	56
480	Chapel	17,500		992,802	57
525	Rader Clinic	54,338		1,555,343	29
Totals		*1,311,481*	*2,956*	*4,520,000,000*	*34**

*Average

Figure 1. Bldg 447 Boiler House.

The existing steam distribution system (Figure 2) is nearing the end of its useful life. This is especially true for the condensate return system, which uses a fiberglass pipe. The application of fiberglass pipe in a condensate return system is uncommon. While fiberglass material will resist corrosion, the resins used in the fiberglass have a temperature limitation in the range of 250 to 350 °F depending on the type used. Steam at 90 psig has a temperature of 331 °F. If a steam trap allows steam to pass through, temperatures in this condensate pipe may approach 300 °F. Since the steam temperature is constant, the temperature of the condensate is relatively high through the year. Thus, a constant high temperature stress is exerted on the fiberglass. The existing steel steam pipe is assumed to be made with schedule 40 and it appears to be in reasonable condition.

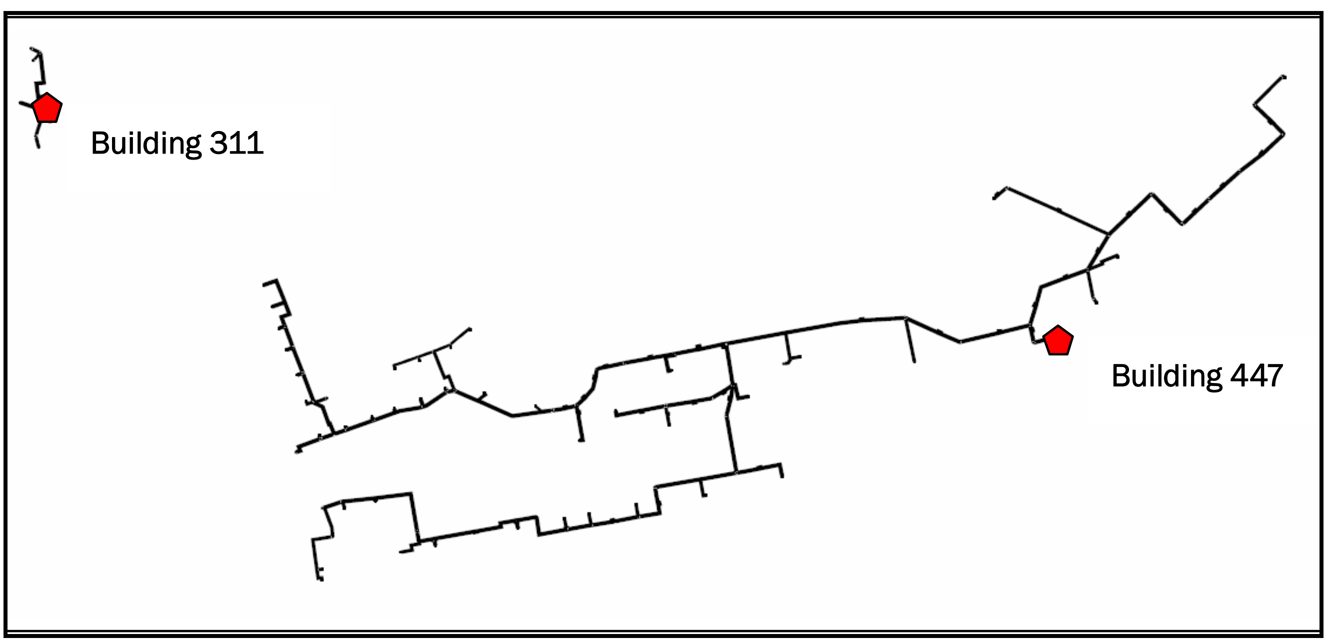

Figure 2. Fort Myer steam distribution system.

Leaks occur frequently in the underground pipe of the deteriorating steam distribution system, and fixing leaks is difficult, time consuming, labor intensive, and expensive. In the past 2 years, Fort Myer has spent nearly $300,000 repairing the underground steam and condensate return lines. The cost for maintaining the underground piping system will continue to grow at an estimated rate of approximately 10 percent a year (not including inflation).

Finding an underground steam leak is not easy. A team of several workers often takes a day to locate the problem. The team must first unearth the pipes in the area where they suspect the leak is located. Once the leak is located, before fixing it, workers must turn off the steam to all users downstream from the nearest valve that will stop the flow of steam to the leak, which halts operations within those buildings that require steam.

Because of the poor performance of this deteriorating system, buildings are being taken off the central system. This includes the general officer living quarters (Buildings 11 through 27), which are now scheduled for the installation of individual heating units.

Nevertheless, the boiler plant at Building 447 is in good condition. The boilers have been recently overhauled, and in 2005, these boilers produced almost 114 million pounds of steam while consuming more than 1.3 million therms of natural gas (cf. Table 2, column 2) and 103,000 gal of fuel oil (column 3) for an energy efficiency of 83 percent. The fuel cost was $895,000 and the energy used was equivalent to 43,739 MWh (column 4).

Problems with the condensate return system cause only a third of the condensate to be returned to the boiler plant, resulting in an additional requirement of 12,262 million Btu (mmBTU) of steam energy (column 10) to heat make-up water. The estimated cost to purchase this additional water is $60,000/yr, and the cost to treat this water with corrosion limiting chemicals adds at least another $18,000/yr to operating costs.

Other demands for steam are building heating needs and losses in the distribution system. The building energy consumed was determined by using heating loads calculated for each building (provided in a report prepared by Honeywell) and multiplying these values by an equivalent 1340 full load hours of heating and a coincidence heating factor of 80 percent. The resulting annual heating demand obtained is 14,201 MWH (column 13).

During the site survey, researchers noted that many of the buildings were being overheated. It was not uncommon to find spaces at more than 80 °F. Also, the buildings were not of "tightly" constructed, i.e., excessive amounts of infiltration air enter the building. Additional heating energy is consumed to warm this air up to room temperatures. The estimated energy waste due to this overheating and infiltration of outside air is estimated to be 30 percent of the normal building consumption or 4,260 MWH of energy * Column 14). This amount was added to the annual building heating loads from the Honeywell information to provide the actual estimated building heating use of 18,462 MWH (column 15).

The domestic hot water steam use was estimated by taking the number of occupants (3,000) in all the buildings, and multiplying a daily use of hot water per occupant (60 L or 15.8 gal/day) times 220 days/yr. The total heating use of domestic hot water is 1,507 MWh/yr (column 12). Since energy losses in the distribution system were difficult to determine, they were estimated by:

Subtracting			
the estimated 30% overheating of	4,260	MWh	(column 14)
the calculated heating energy demand of	14,201	MWh	(column 13)
the estimated domestic hot water demand of	1,507	MWh	(column 12)
the estimated condensate losses of	3,594	MWh	(column 10)
Total	*23,562*	*MWh*	
From the steam input into the system of	36,367	MWh	(column 7).
	–3,594	MWh	
Which amounts to additional heating energy of	32,773	MWh	(43,688 mmBTU) (column 11).

Table 2 lists the 2005 monthly energy use.

Energy is also used to power fans and pumps in the central boiler plant, which consumes an estimated 915,000 kWh of electrical power use, for an annual energy cost of $86,000.

The total annual energy costs for providing steam to the Fort Myer buildings is $982,000.

Added to this are the additional maintenance costs of the stream distribution system, equal to $206,000/yr and a cost of $78,000 for make-up water, yielding a total estimated annual cost of $1,266,000 for operating the steam plant. Appendixes B and C give a detailed summary of these energy uses and costs.

Fuel Consumption Data					Steam Production Data									
Month 2005	Boiler fuel consumption	Boiler fuel consumption	Total Boiler fuel consumption	Monthly portion of annual fuel consumption	Steam Production	Steam Energy Production in MWH equivalent	Production Energy Losses	Condensate Losses	Condensate losses in MWh equivalent	Estimated annual transport and distribution energy losses	Estimated domestic hot water demand	Calculated heating energy demand	Estimated 30% overheating buildings	Total demand in MWh equivalent
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	gas terms	oil gallons	MWh		1,000 LB	MWh	MWh	k gal	MWH	MWh	MWh	MWh	MWh	MWh
Jan	226200	0	6629	15%	17316206	5535	1094	1171	454		126	3044	913	3957
Feb	185800	0	5445	12%	14380014	4597	849	1024	397		126	3078	923	4001
Mar	202000	0	5920	14%	15640091	5000	921	1285	498		126	2323	697	3020
Apr	124000	0	3634	8%	9153690	2926	708	897	347		126	806	242	1048
May	70300	0	2060	5%	5308000	1697	364	471	182		126	0	0	0
Jun	61100	0	1791	4%	4802000	1535	256	419	162		126	0	0	0
Jul	60100	0	1761	4%	4672000	1493	268	418	162		126	0	0	0
Aug	52800	0	1547	4%	4447000	1422	126	348	135		126	0	0	0
Sep	53800	0	1577	4%	4240000	1355	221	352	136		126	17	5	22
Oct	89800	0	2632	6%	6225000	1990	642	563	226		126	572	172	744
Nov	142000	0	4162	10%	10560710	3376	786	969	390		126	1405	422	1827
Dec	78500	102777	6580	15%	17021526	5441	1139	1256	505		126	2956	887	3843
Total	1346400	102777	43739	100%	113766237	36367	7372	9173	3594	12804	1507	14201	4260	18462
			mmBTU			mmBTU	mmBTU		mmBTU	mmBTU	mmBTU	mmBTU	mmBTU	mmBTU
			149236			124083	25153		12262	43688	5141	48454	14536	62991

3 Alternative Heating Systems

Two reasonable alternatives to the existing steam heating system at Fort Myer are:

1. *To convert to a hot water distribution system with variable supply water temperatures*. With this system, the steam boilers would remain and new steam-to-hot-water heat exchangers would be installed at the central plant in Building 447. The resulting hot water would be pumped to the buildings currently receiving steam heat. Each building would have new heat exchangers, packaged together into a compact station, for making domestic hot water and delivering building heat. The domestic hot water heating system would include a storage tank sized to hold 15 gal for each building occupant. A new underground pre-insulated hot water supply pipe would be installed and the present steam pipe would function as the return pipe.
2. *To convert to distributed heating systems*. With this system, a small building addition to each building on the steam system would house a new gas-fired hot water generator (that would heat the building) and a gas-fired domestic hot water heater. These new heating units would be connected to the existing building heating distribution systems.

3.1 Central Plant Hot Water System

The central heating plant with the new hot water distribution system would distribute hot water to all the buildings that now use steam, with the exception of the general officer housing and buildings scheduled for demolition. Table 2 lists the buildings to be served by the new hot water system. The water temperature would vary from a temperature of 275 °F for a design outside temperature of 15 °F to cooler temperatures when less heat is needed due to warmer outdoor temperatures. The total installed estimated cost for this conversion is $3,359,000. This cost covers the central plant heat exchangers with 1,611 sq ft of surface area, pumps, a new supply water distribution system, building heat exchangers, and the necessary controls.

Figure 3 schematically shows the piping system; Figure 4 shows the boiler plant with the steam to hot water heat exchangers; and Figure 5 shows the compact station including space heating and domestic hot water preparation.

Table 2. List of buildings to be served by the new hot water system.

Building Number	Building Function	Compact Station size for Space Heating [MBTUh]	Compact Station size for Domestic Hot Water [MBTUh]	DHW Tank size [gal]
59	Installation HQs	1024	853	1057
237	Fire Dept.	341	85	106
238	Cadet Office	341	85	106
241	Ceremonial Hall	1365	256	264
242	Old Guard HQ	682	85	106
243	Town Hall	341	256	264
246	Company Quarters	2388	171	1585
248	B&D Company Quarters	2388	341	3170
249	3rd Infantrz Museum	1194	171	1585
250	HQ Honor Guard	1024	171	1585
251	Barracks	1024	171	1585
400	Band Training	1706	256	264
404	Tri-Service Dining	1535	409	3963
405	Community Center	853	256	264
407	NCO Club	1024	85	106
410	MP Company Barracks	1194	1194	1585
411	Bowling Center	853	85	106
416	HQ Company Barracks	2047	1194	1585
450	PX Building	1706	256	264
480	Chapel	1194	85	106
525	Rader Clinic	1706	341	3170

The hot water produced in the central heating plant is circulated to the buildings through more than 14,000 ft of new underground pipe using a variable speed pump with a 40-hp motor. A similar pump will be installed as a back-up. The new hot water distribution pipe is steel pipe pre-insulated by polyurethane foam with a high density polyethylene covering. This pipe will come with a leak detection system so that future leaks can be easily located. Expansion and contraction design considerations are not required for pipe with diameters of 8 in. or less. It is expected that one piping crew can install about 100 ft of pipe per day. The installed cost for the new supply pipe is estimated at about $1.5 million. Figure 3 shows the proposed route for this piping.

The existing steam-to-hot-water heat exchangers, the steam pressure reducing stations, and condensate receivers will be removed from each building. This will provide space for the new heat exchangers. The outlet from these hot water to hot water heat exchangers will connect to the building's existing hot water heating system (Figure 4).

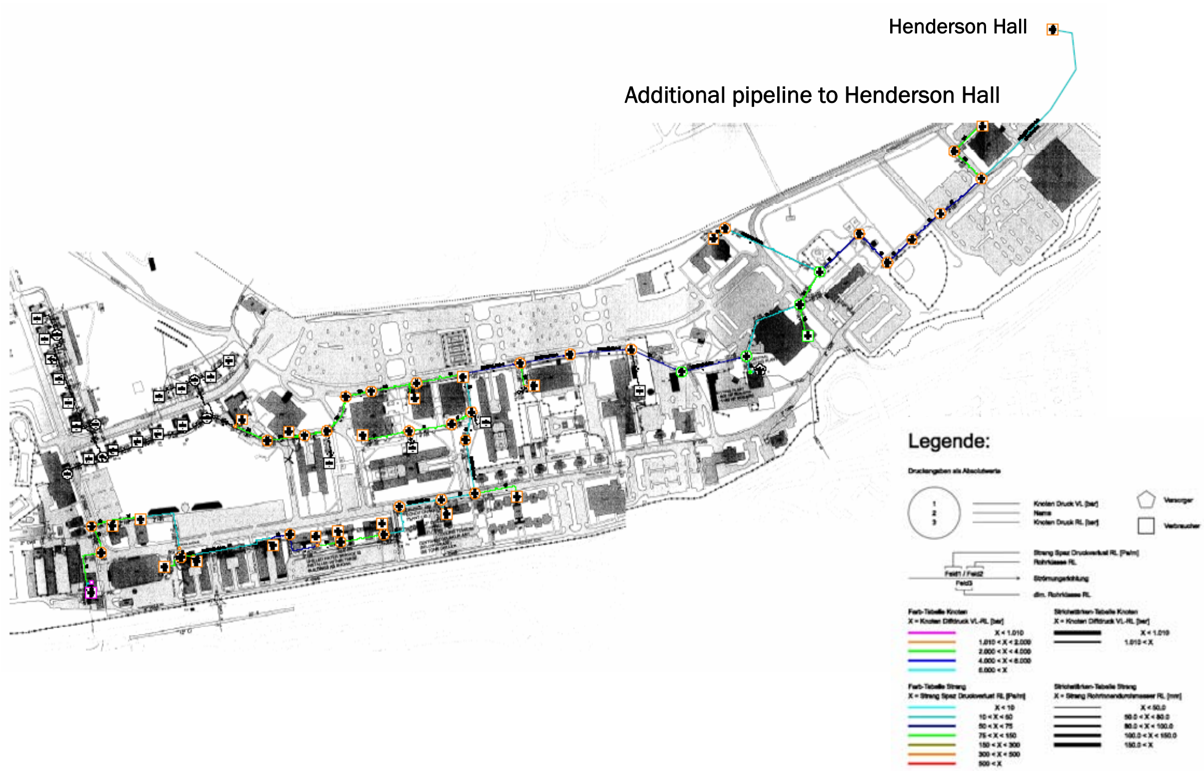

Figure 3. Overview of the new hot water distribution system with a map of Fort Myer in the background.

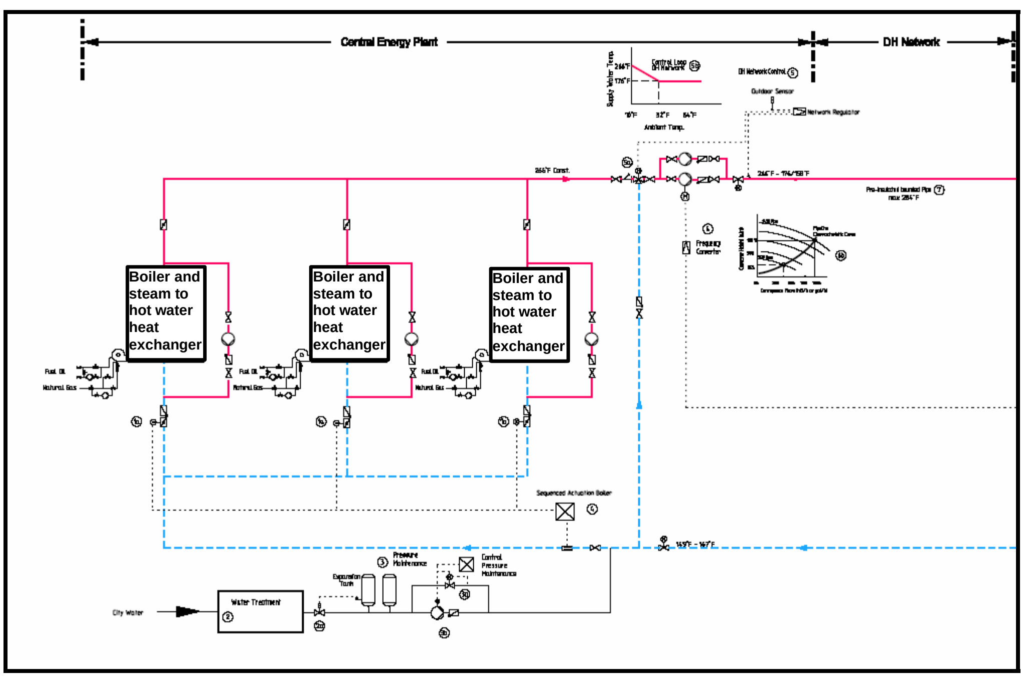

Figure 4. Boiler plant with its three dual-fired boilers and control equipment for hot water distribution network.

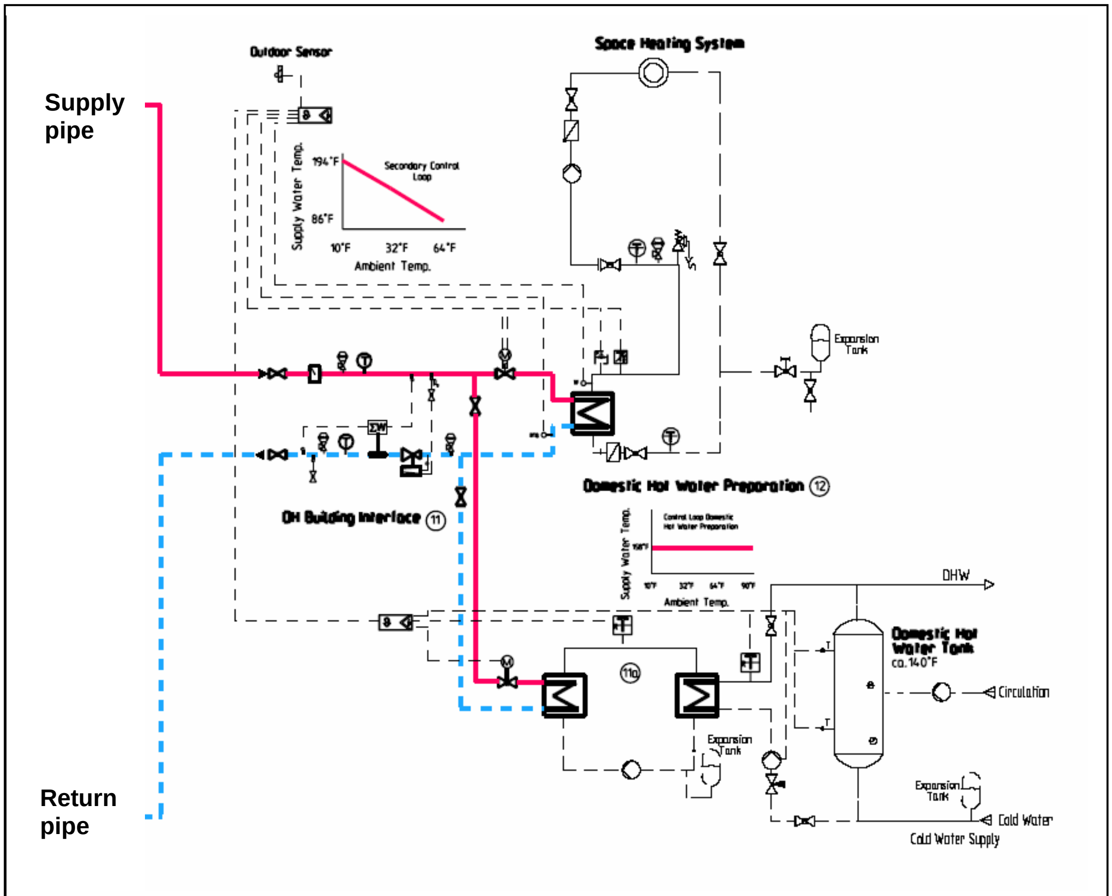

Figure 5. Schematic drawing of the connection of buildings to the primary hot water system.

Controls will be added to monitor the building temperature so the heating system can lower the heating water temperature to minimize the amount of building overheating. A new building addition of 240 sq ft is included in the cost estimate for three buildings in which large domestic hot water heating systems will be installed. Steam is currently used for clothes pressing in the barracks and in the dining hall for cooking and dish washing. The cost estimate includes electric clothes pressing equipment and a small package steam boiler for the steam users in the dining hall.

The piping pressure drops are determined using a computer model of the system. The color of the pipes in Figure 3 indicates the pressure loss (cyan = less than 10 Pa per 3 ft, thru green, to red = more than 500 Pa per 3 ft). The squares indicates the connected buildings and the color indicates the differential pressure (magenta = 1 atm thru green to cyan = more than 6 atm). Figure 3 shows that the critical building is located in the southwestern area (Building 254). Thus one can find the lowest differential pressure with 1 atm. The scattered pipes are not longer connected to the system as

well as the black colored squares. Figure 3 also shows the additional pipeline to Henderson Hall in the northeaster area of the installation.

Figure 5 shows a compact station that contains both the heat exchanger for space heating (No. 11) and for domestic hot water preparation (No. 12). To assist in the transition from the steam to hot water a couple portable steam boilers will be rented to provide temporary steam for domestic hot water in the buildings that require continuous service. It is expected that a working crew can convert a group of four to five buildings in 1 week.

The hot water system will have lower distribution system and building energy losses while delivering more comfortable building temperatures during the heating season. The system will be controlled to provide the hottest water only during the coldest winter days. During other times, the hot water temperature can be lowered and still meet the heating needs. During the summer when the outdoor temperature is higher than 60 °F, heat is only required by the domestic hot water heaters, which only require hot water at a temperature of 175 °F to be supplied. This, in combination with the new compact stations, which offer better controls, will reduce heat losses through the pipe distribution system.

Pre-insulated pipe further lower heat losses relative to the existing pipe due to both better insulation quality and lower supply temperatures. The system will help avoid the energy waste by overheating buildings and lengthen the life of the distribution pipes reducing the stress of expansion and contraction. The closed hot water system will be less susceptible to corrosion and will minimize leaks in the distribution system, which will greatly reduce the make-up water demands on the boiler system in the central heating plant.

The ability to reduce the hot water temperatures will decrease the overheating waste by 50 percent. When added to the savings due to reduced pipe leak and heat losses will yield an estimated energy savings of 44,860 mmBTU/yr. When compared to the existing steam system, this represents an annual cost avoidance of $327,000.

The boiler feed water and condensate return pumps, the hot water distribution pumps, and the combustion fans on the boilers will all require need electrical power. The total estimated electrical power used in a year is 642,000 kWh at a cost of approximately $75,000. This cost is still less

than the cost of electricity for the existing system since the new system produces less steam and requires no remote condensate pumps.

Additionally, the replacement of both return and condensate pipes will further reduce distribution heat losses. Nevertheless, as long as the steam pipes are in use, the replacement is not economical. In the future, whenever a section needs to be replaced, the described pre-insulated pipes can be used to achieve the potential savings.

With this system, the boiler plant can continue to burn natural gas on an interruptible basis since the existing fuel oil tanks will provide an alternative energy source. This allows this plant to operate most of the year using a lower cost gas source. Given the estimated annual fuel consumption of 921,850 mmBTU, the estimated energy cost for generating the hot water is $600,000. This assumes that 12 percent of the fuel used will be No. 2 fuel at a cost of $1.72/gal. The estimated cost for natural gas is $0.923 and $0.49 for summer and winter use, respectively.

The total operation cost of this system is estimated to be $732,000/yr, which includes $57,000 for annual maintenance costs and $19,000 for water costs. This option results in an annual cost saving of $534,000 over the operating cost of the existing steam system. Since the cost to install the hot water equipment is $3,359,000, this system has a simple payback of 6.3 years. The estimated life of the equipment used in this system is in the range of 30 to 40 years, at which time the boilers and return water piping will need replacement. At the same time, some of the major components will also need replacement. Appendixes B and C give a detailed summary of the energy use and costs associated with this system.

Figure 6. Typical domestic hot water heater (~200-gal storage tank).

Figure 7. Typical (left) and larger (right) compact station.

3.2 distributed Building Heating Systems

The distributed building heating system will be fueled by natural gas, which is distributed underground to each building. New boilers and hot water heaters will be installed to service their building. The installation of new heating boilers and hot water heaters will require the addition of a new building space of approximately 400 sq ft in size to the existing buildings to accommodate the new gas-fired heating units. A condensing type steel fire tube hot water boiler will be used for the building heating hot water similar to one shown in Figure 8. This type of unit has an operating efficiency in the range of 87 to 97 percent with the average approximately 92 percent. The hot water heater will be an 83 percent efficient vertical storage type (Figure 9). The hot water from these heating units will connect to the existing building distribution systems. Table 3 lists the buildings to be converted and the proposed size of the distributed heating system.

Table 3. List of the building o be converted to an distributed heating system.

Building No.	Building Function	Condensing Boiler Size		No. Boilers	DHW Tank size (gal)	No. Tanks
		Output (MBTUh)	Input (MBTUh)			
59	Installation HQs	494	565	2	1000	1
237	Fire Dept.	349	399	1	125	1
238	Cadet Office	349	399	1	125	1
241	Ceremonial Hall	697	750	2	400	1
242	Old Guard HQ	494	565	2	125	1
243	Town Hall	349	399	1	400	1
246	Company Quarters	2630	3000	1	1500	1
248	B&D Company Quarters	2630	3000	1	1500	2

Building No.	Building Function	Condensing Boiler Size		No. Boilers	DHW Tank size (gal)	No. Tanks
		Output (MBTUh)	Input (MBTUh)			
249	3rd Infantry Museum	697	750	2	1500	1
250	HQ Honor Guard	494	565	2	1500	1
251	Barracks	697	750	2	1500	1
400	Band Training	875	1000	2	400	1
404	Tri-Service Dining	875	1000	2	1500	1
405	Community Center	494	565	2	400	1
407	NCO Club	494	565	2	125	1
410	MP Company Barracks	697	750	2	1500	1
411	Bowling Center	494	565	2	125	1
416	HQ Company Barracks	2290	2600	1	1500	1
450	PX Building	875	1000	2	400	1
480	Chapel	697	750	2	125	1
525	Rader Clinic	875	1000	2	1500	1

Figure 8. Gas-fired boiler.

Figure 9. Gas-fired domestic hot water heater.

Natural gas service enters the site on the west side of the installation using a 4-in. steel pipe. This line services most of the buildings at Fort Meyer. Gas pipe with a diameter less than 2 in. is of PVC material. The installation has a total of 23,450 ft of natural gas pipe, of with 6,700 ft are PVC type. Near the central heating plant, a 6-in. line is run from the distribution line offsite to fire the boilers and to service a few buildings in this area. The addition of the distributed gas-fired heating systems will add to the natural gas demand by 397,060 therms. The 4-in. pipe distribution system will probably not satisfy this new demand to the buildings; therefore, the estimated cost to upgrade the distribution piping system includes the connection cost to the buildings. Figure 10 shows the proposed new gas distribution system. This piping is estimated to cost $701,000, not including the costs for a new natural gas control station (which may be required).

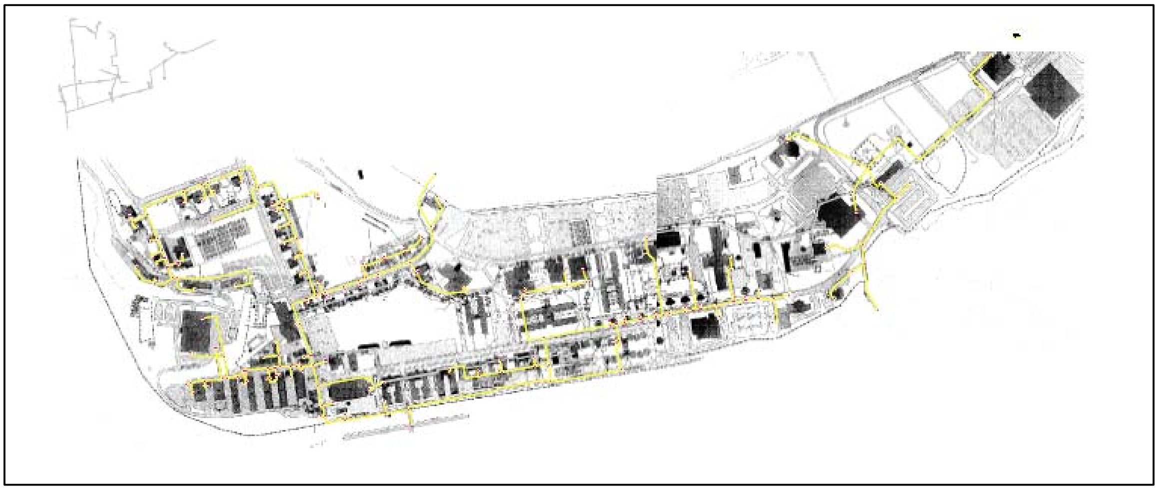

Figure 10. Proposed natural gas distribution system on the installation (pipes highlighted in yellow).

The gas used by the distributed heating systems will need to be purchased using a more costly noninterruptible or firm rate of $1.1805 per therm. Since the estimated annual gas use is 397,060 therms, the energy cost for this system is $469,000. Electrical power will be required to power combustion blowers on the heating units and to ventilate the rooms where the heating units are located. This power requirement is estimated to be 400,000 kWh/yr having a cost of $25,000. The labor for operating and maintaining this equipment is assumed to be similar to operating the central boiler plant, building 447. See more discussion on this topic below. The estimated cost for maintenance parts on the equipment is 2½ percent of the system cost or $113,000/yr. The estimated life of this equipment is in the range of 15 to 20 years, at which time the heating units would need replacement.

This provides a total annual savings off $659,000 when compared to the existing central steam heating system. The estimated installed cost for the distributed systems is $4,774,000. The resulting payback is 7.24 years. Appendixes A and B summarize the energy use and costs.

It has been questioned could the implementation of the distributed heating systems lead to a reduction in the five person operator crew that currently staffs the CEP. This crew presently provides a 24 hours 7 days a week presence at this boiler plant. Two or three of these employees will be required in the operation the distributed system equipment. Their duties will include checking boiler operations, monitoring water treatment systems, evaluating pump and automatic controls performance, and performing annual equipment cleaning and safety checks. Part of the cost of the

The proposed central hot water heating system also had controls associated with it. Approximately $70,000 is estimated for boiler plant controls. (Each of the building substations has controls included.) A central monitoring and control system to the scale required for the distributed system is not required since the hot water system is easier to control. The water temperature can be adjusted to avoid overheating. It should also be noted that additional controls can be added to the central heating plant that would enable it to be operated remotely. The addition of these controls would allow a reduction in the number of operators. If this type of controls is of interest to Fort Myer, it can be further investigated. This remote operation mode is not necessary for the conversion from steam to hot water and requires additional installation costs. However, since new steam-to-hot-water heat exchangers are being constructed at the boiler house, taking the additional measures to make the remote control mode possible would be an easy additional step.

3.3 Cogeneration at Fort Myer

During the assessment, the option for a cogeneration plant at Fort Myer was discussed. The analysis shows that the domestic hot water demand, which is the only heating use during the summer (April trough October), is too small to be economically connected to an electrical generation unit. The presumed CHP plant would be a natural gas fired motor with an electrical capacity of 200 kW_{el} and a thermal capacity of less than 250 kW_{th} or 853,150 BTU. Since the electrical capacity of the unit would have no noteworthy impact on the electrical usage at Fort Myer the option was not further investigated.

4 Henderson Hall and Fort McNair

Henderson Hall and Fort McNair are both installations under the authority of Fort Myer's DPW, and both were assessed. A detailed analysis was performed for Henderson Hall. Since Henderson Hall and Fort Myer are adjacent to each other, the recommended solution for Henderson Hall will depend strongly on the decision made on the Fort Myer heating system.

Henderson Hall has five buildings served by a central steam system located at the Pentagon (Table 4). That service will soon be terminated (presumably in 2009) because the adjoining "Naval Annex" building complex is being demolished, thus removing the connecting steam line. Henderson Hall has two 100 boiler horsepower (6,670 MBH) units that could be fired with some modifications to heat the buildings. The options evaluated are:

1. Operating the two sites on independent steam systems
2. Connecting the buildings to the hot water system at Fort Meyer
3. Using the existing steam boilers located in Building 28 making the Henderson Hall heating system independent from the Fort Meyer hot water system.

4.1 Steam System at Fort Meyer and Henderson Hall Independent Steam System

The independent system would use the existing two steam boilers located in Building 28 and would require the addition of a third, similarly sized boiler in an unoccupied space in Building 28. The estimated cost of this installation is $164,000.

The energy usage of the five buildings was estimated based on the average steam use from FY 1994 through FY 1998 (17,520 mmBtu/yr). If the boilers have a 3 percent blowdown and are 85 percent efficient, the energy input is 20,800 mmBTU/yr. This equates to approximately 20,800 therms, which would cost $1.18 per therm for a total annual cost of $245,000. Together with existing Fort Myer Steam plant operating costs, the total fuel cost would be $1,141,000/yr. The electrical energy cost would increase to $100,000. The maintenance cost is projected to be $303,000/yr. The increased annual cost for water and chemicals is $83,000. The total operating costs of the Fort Myer and Henderson Hall Steam systems would be $1,628,000/yr. Appendixes B and C give a detailed summary of the energy use and costs associated with this system.

Table 4. Listing of Building at Henderson Hall.

Building No	Function	No. People	sq ft	Garages	Net sq ft	Specific heat load (Btu/sq ft)	Heating load (Btu)	DHW load (Btu)
12	DPW office , Shops	23	11,737		11,737	20	234,740	0
25	Barracks, Dining Admin	350	290,653	162,028	128,625	21	2,701,125	1,140,000
26	Post Exchange	347	173,354	78,200	95,154	20	1,903,080	0
27	Gym	63	31,463		31,463	15	471,945	65,000
28	Warehouse, Admin	48	36,500		36,500	10	365,000	0

4.2 Henderson Hall Heated By Fort Myer Hot Water System

This option would expand the Fort Myer hot water system to include the Henderson Hall buildings. To deliver hot water to Henderson Hall, the hot water distribution piping will need to be extended at an estimated cost of $667,000. The hot water pumping equipment will also need to be slightly increased. An additional $122,000 is estimated to provide the installation with individual building compact stations. The resulting total cost for the expanded Central Hot Water System for the total complex is $3,680,000.

Adding these five buildings to the system will increase the fuel cost to $747,000/yr. The electrical operating costs will increase to $94,000 bringing the annual energy cost to $841,000. Add to this $21,000 for water and chemicals and $59,000 for maintenance the total annual operating costs is $921,000. This is $707,000/yr less than the all steam system annual costs. The resulting payback is 5.2 years. Appendixes B and C give a detailed summary of the energy use and costs associated with this system.

4.3 Hot Water System at Fort Meyer and Henderson Hall Independent Steam System

In this option, each installation will be operated independently. Fort Myer will convert to the hot water system. Henderson Hall will use its own independent heating system. Section 4.1 discussed the cost of the upgrade of the Henderson Hall boilers. When added to cost of the Fort Myer hot water system, the total installed cost of these systems is $3,573,000.

Heating the Henderson Hall buildings will increase the fuel cost of the Fort Myer hot water system to $825,000/yr. With the annual electrical cost of $98,000, the annual energy cost will be $913,000. The water/chemical and maintenance costs will be $21,000 and $156,000, respectively, for a total operating cost of $1,090,000/yr. The resulting pay-

back period for this option is 6.7 years. Appendixes B and C give a detailed summary of the energy use and costs associated with this system.

4.4 Fort McNair

Fort McNair is located on the Potomac River in Washington, DC. The buildings found at this installation are residential, administrative, and training facilities. A central heating plant burns natural gas to provide steam for heating in 18 of almost 60 building on the site. It has been proposed that a distributed heating or central hot water heating system may be a better system for providing this heat.

The current heating system consists of two 500 bhp boilers located in Building 34. These boilers are in good condition and have an efficient operation. Both fuel oil and natural gas are available fuels to these boilers. There is approximately 3600 ft of underground steam lines that deliver the steam to the buildings, and a similar length of condensate return lines. The buildings served by the steam plant are grouped in two areas approximately 200 ft apart. Within these groups most of the buildings are close together, making individual heating boilers for each building impractical. These groups of buildings could be served by their own boiler systems, but that approach is almost the same as using the existing one central boiler plant. The total area of the 18 buildings served is approximately 1800 by 750 ft (not a large space compared to other installations). Therefore the one central heating plant is the best application for Fort McNair.

Since the use of one central heating plant is the best solution for Fort McNair, it is appropriate to continue to operate the existing heating system and maintain it well to lengthen its useful life. Whenever the number of pipe leaks increases dramatically and the boilers need to be replaced, a conversion to a hot water system should be investigated

5 Conclusions

This study evaluated the performance of the heating systems at Fort Myer and Fort McNair, developed retrofit options, and conducted technical and economic analysis for three options:

1. Continue to produce steam for distribution (base case)
2. Switch to a hot water distribution system (hot water central system)
3. Abandon the central plant at 447 and install individual building heating systems (distributed system).

An evaluation of the three alternatives showed that a hot water heating conversion will provide the lowest life cycle cost and allow the most fuel flexibility.

This study also analyzed two heating options for neighboring Henderson Hall (for which Fort Myer manages installation support): (1) Connecting Henderson Hall buildings to the new hot water distribution system proposed to serve Fort Myer, or (2) using the existing steam heating plant in Building 28 to heat the five Henderson Hall buildings. A life cycle cost analysis showed that the expansion of the hot water system is the most cost effective choice.

Appendix A: Life Cycle Cost Analysis

NIST BLCC 5.3-05: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

These life cycle cost (LCC) calculations are based on the Federal Energy Management Program (FEMP) discount rates and energy price escalation rates updated on 1 April 2005.

Location:	Virginia	Discount Rate:	3%
Project Title:	Meyer	Analyst:	David Underwood
Base Date:	January 1, 2007	Preparation Date:	Thu Sep 07 21:49:48 CDT 2006
BOD:	January 1, 2007	Economic Life:	20 yrs 0 mo
File Name:	C:\Program Files\BLCC5\projects\Meyer_HotWaterDistHeat.xml		

1. Investment

Construction Cost	$3,359,000
SIOH	$191,463
Design Cost	$335,900
Total Cost	$3,886,363
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$3,886,363

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$27.60730	379.2 MBtu	$10,470	14.984	$156,882
Distillate Fuel Oil (#1, #2)	$11.33315	3,650.8 MBtu	$41,375	15.503	$641,427
Natural Gas	$8.09997	33,740.2 MBtu	$273,295	14.446	$3,948,064
Energy Subtotal		37,770.2 MBtu	$325,139		$4,746,372
Water Usage	$5000.00	9.0 Mgal	$44,804	15.099	$676,493
Water Subtotal		9.0 Mgal	$44,804		$676,493
Total			$369,944		$5,422,866

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Annually Recurring	$162,800	Annual	39.251	$6,390,076
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$162,800			$6,390,076

4. First year savings	$532,744	
5. Simple Payback Period (in years)	7.29	(total investment/first-year savings)
6. Total Discounted Operational Savings	$11,812,942	
7. Savings to Investment Ratio (SIR)	3.04	(total discounted operational savings/ total investment)
8. Adjusted Internal Rate of Return (AIRR)	8.89%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-05: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2005.

Location:	Virginia	Discount Rate:	3%
Project Title:	Meyer	Analyst:	David Underwood
Base Date:	January 1, 2007	Preparation Date:	Thu Sep 07 21:50:53 CDT 2006
BOD:	January 1, 2007	Economic Life:	20 yrs 0 mo
File Name:	C:\Program Files\BLCC5\projects\Meyer_UnitaryHeating.xml		

1. Investment

Construction Cost	$4,774,000
SIOH	$272,118
Design Cost	$477,400
Total Cost	$5,523,518
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$5,523,518

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$27.60730	2,207.7 MBtu	$60,949	14.984	$913,258
Distillate Fuel Oil (#1, #2)	$11.33315	13,751.3 MBtu	$155,846	15.503	$2,416,064
Natural Gas	$8.09997	33,380.9 MBtu	$270,384	14.446	$3,906,021
Energy Subtotal		49,340.0 MBtu	$487,179		$7,235,343
Water Usage	$5000.00	11.9 Mgal	$59,739	15.099	$901,991
Water Subtotal		11.9 Mgal	$59,739		$901,991
Total			$546,918		$8,137,334

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Annually Recurring	$111,453	Annual	37.182	$4,144,002
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$111,453			$4,144,002

4. First year savings	$658,371	
5. Simple Payback Period (in years)	8.39	(total investment/first-year savings)
6. Total Discounted Operational Savings	$12,281,336	
7. Savings to Investment Ratio (SIR)	2.22	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	7.20%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-05: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2005.

Location:	Virginia	Discount Rate:	3%
Project Title:	Meyer	Analyst:	David Underwood
Base Date:	January 1, 2007	Preparation Date:	Thu Sep 07 21:51:34 CDT 2006
BOD:	January 1, 2007	Economic Life:	20 yrs 0 mo
File Name:	C:\Program Files\BLCC5\projects\Meyer_Henderson_HotWaterDist.xml		

1. Investment

Construction Cost	$4,774,000
SIOH	$272,118
Design Cost	$477,400
Total Cost	$5,523,518
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$5,523,518

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$27.60730	241.0 MBtu	$6,652	14.984	$99,674
Distillate Fuel Oil (#1, #2)	$11.33315	332.5 MBtu	$3,769	15.503	$58,423
Natural Gas	$8.09997	47,894.2 MBtu	$387,941	14.446	$5,604,268
Energy Subtotal		48,467.7 MBtu	$398,362		$5,762,365
Water Usage	$5000.00000	9.0 Mgal	$45,218	15.099	$682,740
Water Subtotal		9.0 Mgal	$45,218		$682,740
Total			$443,580		$6,445,105

3. Non-Energy Savings (+) or Cost (-)

4. First year savings	$705,012	
5. Simple Payback Period (in years)	7.83	(total investment/first-year savings)
6. Total Discounted Operational Savings	$16,829,820	
7. Savings to Investment Ratio (SIR)	3.05	(total discounted operational savings/total investment)
8. Adjusted Internal Rate of Return (AIRR)	8.90%	(1+d)*SIR^(1/n)-1; d=discount rate, n=years in study period

NIST BLCC 5.3-05: ECIP Report

Consistent with Federal Life Cycle Cost Methodology and Procedures, 10 CFR, Part 436, Subpart A

The LCC calculations are based on the FEMP discount rates and energy price escalation rates updated on April 1, 2005.

Location:	Virginia	Discount Rate:	3%
Project Title:	Meyer	Analyst:	David Underwood
Base Date:	January 1, 2007	Preparation Date:	Thu Sep 07 21:52:11 CDT 2006
BOD:	January 1, 2007	Economic Life:	20 yrs 0 mo
File Name:	C:\Program Files\BLCC5\projects\Meyer_Henderson_Steam.xml		

1. Investment

Construction Cost	$4,774,000
SIOH	$272,118
Design Cost	$477,400
Total Cost	$5,523,518
Salvage Value of Existing Equipment	$0
Public Utility Company	$0
Total Investment	$5,523,518

2. Energy and Water Savings (+) or Cost (-)

Base Date Savings, unit costs, & discounted savings

Item	Unit Cost	Usage Savings	Annual Savings	Discount Factor	Discounted Savings
Electricity	$27.60730	465.1 MBtu	$12,840	14.984	$192,395
Distillate Fuel Oil (#1, #2)	$11.33315	3,650.8 MBtu	$41,375	15.503	$641,427
Natural Gas	$8.09997	33,740.2 MBtu	$273,295	14.446	$3,948,064
Energy Subtotal		37,856.1 MBtu	$327,509		$4,781,885
Water Usage	$5000.00000	9.0 Mgal	$45,218	15.099	$682,740
Water Subtotal		9.0 Mgal	$45,218		$682,740
Total			$372,727		$5,464,626

3. Non-Energy Savings (+) or Cost (-)

Item	Savings/Cost	Occurrence	Discount Factor	Discounted Savings/Cost
Annually Recurring	$164,432	Annual	38.712	$6,365,522
Non-Annually Recurring				
Non-Annually Recurring Subtotal	$0			$0
Total	$164,432			$6,365,522

Appendix B: Cost Comparison of Heating Alternatives

Fort Meyer	Cost Comparison of Building Heating Alternatives		
			12-Jun-06
Cost Item	Base Case - Do Nothing	Central Sys. - Hot Water	Distributed System
First Cost Requirements			
Central Plant Items			
Pumping System	$	$22,500.00	$
Steam to Hot Water Exchangers	$	$120,000.00	
Controls	$	$60,000.00	$
Subtotal	$	$202,500.00	$
Distribution System			
New Hot Water Piping	$	$1,464,384.44	$
New Natural Gas Piping	$	$	$701,000
Manholes	$	$29,100.00	$
Subtotal	$	$1,493,484	$701,000
Building Equipment			
Building Converter Stations	$	$416,438.00	$
DHW Heat Exchangers	$	$423,750.00	$
Gas Fired Hot Water Generators	$	$	$1,083,000
Gas Fired DHW Generators	$	$	$1,085,361
Building Additions	$	$28,800.00	$969,360
Removal of old heat exchangers	$	$44,000.00	$
Misc. Piping	$	$	$282,000
Flue/Stacks	$	$	$92,000
Controls	$	$	$464,000
Rental Boiler		$50,000.00	
Alternatives/Makeshifts (pressing)	$	$80,000.00	$80,000.00
Misc. Investments	$	$150,000.00	$50,000.00
Subtotal	$	$1,192,988	$4,105,721
Subtotal First Costs		2,888,972	4,806,721
Contingency 10%		288,897	410,572
Subtotal		3,177,870	4,516,293

SIOH 5.7 %		181,139	257,429
Total First Costs	$	$3,359,008	$4,773,722
Annual Operating & Maintenance			
Energy			
Natural Gas	$740,664.00	$465,806.00	$468,733
Fuel Oil	$154,940.00	$113,806.00	$
Electricity			
Return Condensate Pumps	$9,038.00	$6,635.00	$
Boiler Feed Pumps	$71,522.00	$48,189.00	
Hot Water Distribution Pumps	$	$15,266.00	$
Combustion Fans - Boilers	$5,608.00	$5,608.00	$22,543
Ventilation Fans in Bldg Mech. Rms.			$2,676
Subtotal	$981,772.00	$655,310.00	$493,952.00
Water	$59,739.00	$14,934.75	
Boiler Chemicals	$18,000.00	$4,500.00	
Subtotal	$77,739.00	$19,434.75	$
Maintenance steam stations	$43,400.00	$20,000.00	$
Boilers	$22,960.00	$22,960.00	$112,907
Distribution System	$140,000.00	$14,099.95	$
Misc. Equipment	$	$	$
Subtotal	$206,360.00	$57,059.95	$112,907.33
Total	$1,265,871.00	$731,804.70	$606,859.33
Savings relative to Base Case	$	$534,066.30	$659,011.67
Pay Back Time, years		6.29	7.24
Non-Annual Maintenance/Replacement			
System life 30 yrs			
Equipment replaced	at 30 yrs	at 30 yrs	at 15 yrs

Fort Meyer	Cost Comparison of Building Heating Alternatives		
			12-Jun-06
Cost Item	Existing Fort Meyer Steam	Central Sys. - Hot Water	Central Sys. - Hot Water
	With Henderson Hall on Steam	With Henderson Hall	With Henderson Hall on Steam
First Cost Requirements			
Central Plant Items	$140,919		$140,919
Pumping System		$25,000	$22,500
Steam to Hot Water Exchangers		$120,000	$620,000
Controls		$60,000	$60,000
Subtotal	$140,919	$205,000	$205,000
Distribution System			
New Hot Water Piping		$2,131,183	$1,464,384
New Natural Gas Piping		$	$
Manholes		$29,100	$29,100
Subtotal	$	$2,160,283	$1,493,484
Building Equipment			
Building Converter Stations		$489,608	$416,438
DHW Heat Exchangers		$437,250	$423,750
Gas Fired Hot Water Generators		$	$
Gas Fired DHW Generators		$	
Building Additions		$28,800	$28,800
Removal of old heat exchangers	$	$54,000	$44,000
Misc. Piping		$	$
Flue/Stacks		$	$
Controls		$	$
Rental Boiler		$50,000	$50,000
Alternatives/Makeshifts (pressing)		$80,000	$80,000
Misc. Investments		$175,000	$190,000
Subtotal	$	$1,314,658	$1,232,988
Subtotal First Costs	$140,919	$3,679,941	$3,072,391
Contingency 10%	$14,092	$367,994	$307,239
Subtotal	$155,011	$4,047,935	$3,379,631
SIOH 5.7 %	$8,836	$230,732	$192,639
Total First Costs	$163,847	$3,679,941	$3,572,270

Fort Meyer	Cost Comparison of Building Heating Alternatives		
Annual Operating & Maintenance			
Energy			
Natural Gas	$985,915	$595,754	$711,057
Fuel Oil	$154,940	$151,194	$113,806
Electricity			
Return Condensate Pumps	$10,494	$8,091	$8,091
Boiler Feed Pumps	$82,522	$58,769	$58,769
Hot Water Distribution Pumps		$21,454	$15,266
Combustion Fans - Boilers	$7,558	$5,608	$5,608
Ventilation Fans in Bldg Mech. Rms.			
Subtotal	$1,241,429	$840,870	$912,597
Water	$60,317	$15,099	$15,099
Boiler Chemicals	$18,500	$6,000	$6,000
Subtotal	$83,317	$21,099	$21,099
Maintenance steam stations	$58,624	$20,000	$30,000
Boilers	$104,961	$22,960	$109,960
Distribution System	$139,907	$16,100	$16,100
Misc. Equipment	$	$	$
Subtotal	$303,492	$59,060	$156,060
Total	$1,623,738	$921,029	$1,089,756
Savings relative to Base Case		$707,209	$538,482
Pay Back Time, yrs		5.24	6.69
Non-Annual Maintenance/Replacement			
System life 30 yrs			
Equipment replaced	at 30 yrs	at 30 yrs	at 30 yrs

Appendix C: Energy Use Summary

Distributed heating System Energy Cost

Bldg No.	Building Function	Heating System		Condensing Boiler Size		Non-Cond. Boiler Size	No. Boilers	DHW Tank size	No. Tanks	Calculated Bldg heat Demand	Full Load Hours
				Output	Input	Input				BTUh	
				MBTUh	MBTUh	MBTUh					
59	Post HQs	Central Plant	Steam	494	565		2	1000	1	799,041	1340
236											
237	Fire Dept.	no data	No data	349	399		1	125	1	240,248	1340
238	Cadet Office	Central Plant	Steam	349	399		1	125	1	262,040	1340
241	Ceremonial Hall	Central Plant		697	750		2	400	1	1,215,764	1340
242	Old Guard HQ	Central Plant		494	565		2	125	1	573,122	1340
243	Town Hall	Central Plant	Steam	349	399		1	400	1	257,976	1340
246	Company Quarters	Central Plant	Steam	2630	3000	*	1	1500	1	2,224,995	1340
248	B&D Company Quarters	Central Plant	Steam	2630	3000	*	1	1500	2	2,232,535	1340
249	3rd Infantry Museum	Central Plant	Steam	697	750		2	1500	1	1,010,397	1340
250	HQ Honor Guard	Central Plant	Steam	494	565		2	1500	1	888,699	1340
251	Barracks	Central Plant	Steam	697	750		2	1500	1	919,714	1340
400	Band Training	Central Plant	Steam	875	1000		2	400	1	1,557,563	1340
404	Tri-Service Dining	Central Plant	Steam	875	1000		2	1500	1	1,346,904	1340
405	Community Center	Central Plant	Steam	494	565		2	400	1	686,750	1340
407	NCO Club	Central Plant	Steam	494	565		2	125	1	883,001	1340
410	MP Company Barracks	Central Plant	Steam	697	750		2	1500	1	1,006,910	1340
411	Bowling Center	Central Plant	Steam	494	565		2	125	1	763,180	1340
416	HQ Company Barracks	Central Plant	Steam	2290	2600	*	1	1500	1	1,811,185	1340
450	PX Building		Steam	875	1000		2	400	1	1,639,536	1340
480	Chapel	Central Plant	Steam	697	750		2	125	1	992,802	1340
525	Rader Clinic	Central Plant	Steam	875	1000		2	1500	1	1,555,343	1340
	TOTALS									22,867,705	

Bldg No.	Building Function	Annual Heat Req'd MMBH	Building Inefficiencies 20%	Total Annual Heating Gas Use, MMBH	Heating System Efficiency	Gas Use/Yr MMBH	Gas Use Therms/ yr	Boiler Fan kW	Hrs operating Per Yr.
59	Post HQs	1,071	214	1,285	0.92	1,164	11,638	1.68	4200
236									
237	Fire Dept.	322	64	386	0.92	350	3,499	1.68	4200
238	Cadet Office	351	70	421	0.92	382	3,817	1.68	4200
241	Ceremonial Hall	1,629	326	1,955	0.92	1,771	17,708	1.92	4200
242	Old Guard HQ	768	154	922	0.92	835	8,348	1.68	4200
243	Town Hall	346	69	415	0.92	376	3,757	1.68	4200
246	Company Quarters	2,981	596	3,578	0.9	3,313	33,128	6	4200
248	B&D Company Quarters	2,992	598	3,590	0.9	3,324	33,240	6	4200
249	3rd Infantry Museum	1,354	271	1,625	0.92	1,472	14,717	1.92	4200
250	HQ Honor Guard	1,191	238	1,429	0.92	1,294	12,944	1.68	4200
251	Barracks	1,232	246	1,479	0.92	1,340	13,396	1.92	4200
400	Band Training	2,087	417	2,505	0.92	2,269	22,686	2.26	4200
404	Tri-Service Dining	1,805	361	2,166	0.92	1,962	19,618	2.26	4200
405	Community Center	920	184	1,104	0.92	1,000	10,003	1.68	4200
407	NCO Club	1,183	237	1,420	0.92	1,286	12,861	1.68	4200
410	MP Company Barracks	1,349	270	1,619	0.92	1,467	14,666	1.92	4200
411	Bowling Center	1,023	205	1,227	0.92	1,112	11,116	1.68	4200
416	HQ Company Barracks	2,427	485	2,912	0.9	2,697	26,967	6	4200
450	PX Building	2,197	439	2,636	0.92	2,388	23,880	2.26	4200
480	Chapel	1,330	266	1,596	0.92	1,446	14,460	1.92	4200
525	Rader Clinic	2,084	417	2,501	0.92	2,265	22,654	2.26	4200
	TOTALS	30,643				33,510	335,102		
						9818 MWh/yr			

Bldg No.	Building Function	Boiler Electrical Use Kwh/yr	DHW Heater Electrical HP	Hrs/ day	DHW Heater Electrical Use, Kwh/yr	Combustion Air, CFM	Fan hp	Annual KW @ 8760 hrs
59	Post HQs	14112	1	4	1400	757	0.25	1,634
236								
237	Fire Dept.	7056	0.25	4	350	194	0.25	1,634
238	Cadet Office	7056	0.25	4	350	194	0.25	1,634
241	Ceremonial Hall	16128	0.33	4	462	585	0.25	1,634
242	Old Guard HQ	14112	0.25	4	350	432	0.25	1,634
243	Town Hall	7056	0.33	4	462	227	0.25	1,634
246	Company Quarters	25200	1	4	1400	1,365	0.50	3,267
248	B&D Company Quarters	25200	1	4	2800	1,495	0.50	3,267
249	3rd Infantry Museum	16128	1	4	1400	748	0.25	1,634
250	HQ Honor Guard	14112	1	4	1400	627	0.25	1,634
251	Barracks	16128	1	4	1400	748	0.25	1,634
400	Band Training	18984	0.33	4	462	748	0.25	1,634
404	Tri-Service Dining	18984	1	4	1400	910	0.50	3,267
405	Community Center	14112	0.33	4	462	465	0.25	1,634
407	NCO Club	14112	0.25	4	350	432	0.25	1,634
410	MP Company Barracks	16128	1	4	1400	878	0.25	1,634
411	Bowling Center	14112	0.25	4	350	432	0.25	1,634
416	HQ Company Barracks	25200	1	4	1400	1,235	0.50	3,267
450	PX Building	18984	0.33	4	462	748	0.25	1,634
480	Chapel	16128	0.25	4	350	552	0.25	1,634
525	Rader Clinic	18984	1	4	1400	910	0.50	3,267
	TOTALS	338,016Kwh/yr			19,810 Kwh/yr			42,477 Kwh/yr

							TOTALS
Average domestic hot water demand, all inc., showers, washing, dish cleaning etc.	70	liters per day	35	dt (K)	8 GJ	2.32 kWh	
N of maximal present people in Fort Myer (rounded)	3,000						
Assumed daily coincidence of occupation of barracks and facilities	80%						
Assumed average presence out of 365 days	220	days					
Annual domestic hot water demand	36,960,000		35	dt (K)	5,420,184 GJ	1,507 MWh	5,143 MMBTUh, 83 6,196 MMBTUh, 61,961 Therms
Daily domestic hot water demand						7 MWh	
ENERGY USE AND COST SUMMARY							
			Therms/yr	Cost/unit	Cost/yr		
Natural Gas Use, Bldg Heating, Therms			335,102				
Natural Gas Use, DHW Heating, Therms			61,961				
Total Gas Used =			397,063	1.1805	$ 468,733		
Boiler Electricity used		357,826	Kwh/yr	0.063	$ 22,543		
Fan Electricity Used		42477	Kwh/yr	0.063	$ 2,676		
Annual Maintenance Cost							
Equipment Cost =		4,516,293					
Maintenance @ 2.5% =					$ 112,907		
Total Annual Cost					$ 606,859		

Henderson Hall — Hot Water Heating with Steam Heat

2005 Building Heating Use Ref B	14201	MWH/a
Energy use by Buildings to be Removed - Ref C	2292	MWH/a
Projected energy Use by remaining bldg	11909	MWH/a
Building Losses 20 % of Bldg Heat	2382	MWH/a
DHW Heating Use	1507	MWH/a
Make-up Water Heating Ref A	1594	MWH/a
Distribution Losses	5067	MWH/a
Total Projected energy Use by Hot Water Sys	22459	MWH/a
Total Energy Output	76652	Million BTUH
Total Input Energy 83.5% boiler Efficiency =	27,010	MWH/a
Total Energy Input	92185	Million BTUH

Average Steam use per year (FY 94 - FY 98) Ref A =		16,830,000	Pounds
	Btu/ lb of steam (steam @ 100 psi, Cond 180F) =	1041	
Annual Million BTUh Use =		17,520	MMBH
Make-up water heating (55F to 220 F) @ 3% blowdown		139	MMBH
Total heating output		17,659	MMBH
Total Heat input Boiler @ 85% efficient =		20,775	MMBH
Annual Therms used		207,752	Therms
Annual cost @	$1.18 Per therm =	$245,251	

Losses Fort Meyer 4-19.xls = Ref A

Heating Demand Estimates 3-26.xls = Ref B

Fort Meyer heating demand 060508.xls, 4th tab - Ref C

Projected Hot Water System Energy Use

Fuel Use =		92,185	Million BTUh
Summer Use =		42%	of time, 5 months
Distribution =		2108	MWH/a
Makeup Water		663	MWH/a
DHW		627	MWH/a
Total Summer		3398	MWH/a
Total Summer energy Use in Nat gas		138886	Therms
Cost/therm =		0.923	Dollars
Total Winter Use		22941	MWH/a
Total Winter energy =		78296	Million Btu/yr
Total Nat Gas	88%	68901	Million Btu/yr
Total Fuel oil =	12%	9396	Million Btu/yr
Total Nat Gas		689009	Therms
Total Fuel oil =		66166	gallons
Fuel Oil cost =		1.72	Per gallon
Nat. Gas Cost =		0.49	Per therm
Summer cost		128,192	Dollars
Winter Cost		337,614	Dollars
Henderson Hall Gas cost =		$ 245,251	Dollars
Total natural Gas Cost		711,057	Dollars
Fuel Oil Cost		113,806	Dollars

Electrical

Return Condensate Pumps

Steam Produced =	76652000	pounds =	9182910	gal	0.1198	gal per pound
Make-up water =	5%	for Blowdown	459145	gal		
Condensate return water =			8723764	gal or	16.6	gal/min
Pump energy At 8.5 gpm & 30 ft head =			0.13	water horsepower average/minute		
Motor Hp @ 70 % efficiency =			0.18	Motor horsepower average/minute		
Electrical use =		70,432	kWh/yr	$	6,635	Per year
Total Electrical Use		15,464		$	8,091	

Henderson Hall Electrical

Return Condensate Pumps

Steam Produced =	16,830,000	pounds =	2,016,234	gal	0.1198	gal per pound
Make-up water =	5%	for Blowdown	100,812	gal		
Condensate return water =			1,915,422	gal or	3.6	gal/min
Pump energy At 8.5 gpm & 30 ft head =	0.03		water horsepower average/minute			
Motor Hp @ 70 % efficiency =			0.04	Motor horsepower average/minute		
Electrical use =		15,464	kWh/yr	$ 1,457		Per year

Boiler Feed Pumps

Steam Produced =	76652000	pounds =	9182910	gal
Boiler feed water =	17.5	gal/min		
Steam Produced =	16,830,000	pounds =	2016234	gal

Boiler feed water @ 90 psi or 207 feet head					
Pump energy At 25.9 gpm & 207 ft head =	0.91	water horsepower average/minute			
Motor Hp @ 70 % efficiency =	1.30	Motor horsepower average/minute			
Electrical use =	511,560	kWh/yr	$	48,189	Per year
Total Electrical Use	623,880	$	58,769		

Boiler Feed Pumps

Boiler feed water =	3.8	gal/min		
Boiler feed water @ 90 psi or 207 feet head				
Pump energy At 25.9 gpm & 207 ft head =	0.20	water horsepower average/minute		
Motor Hp @ 70 % efficiency =	0.29	Motor horsepower average/minute		
Electrical use =	112,320	kWh/yr	$ 10,581	Per year

Combustion Fans - Boilers			Hrs operating			
		kW use	Winter	Summer	kWh/yr	Total kWh/yr
20,000 lb steam boiler - 10 hp fan		7.46	5040		37598	
10,000 lb steam boiler - 5 hp fan		3.73	2160	3720	21932	
					59,531	kWh/yr
Winter Hrs	3 months large & small boilers on		2160	hrs/yr	$ 5,608	Per year
Winter Hrs	4 months large boiler on		2880	hrs/yr		
Summer	5 months small boiler on		3720	hrs/yr		
Total Electrical Use					$ 7,558	

Combustion Fans - Boilers			Hrs operating			
		KW use	Winter	Summer	kWh/yr	Total kWh/yr
2 @3,500 lb steam boiler - 2 hp fan		3	5040		15120	
1 @ 3,500 lb steam boiler - 2 hp fan		1.5		3720	5580	
					20,700	kWh/yr
Winter Hrs	7 months two boilers on		5040	hrs/yr	$ 1,950	Per year
Summer	5 months one boiler on		3720	hrs/yr		

Hot Water Distribution Pumps	From GEF	15,266	Per year	Total Electrical use =	148,484	kWh/yr
				Electrical Cost per kWh =	0.0942	Per kWh
				Total Electrical Cost per yr =	$ 13,987	
				Maintenance Costs		
				Repair underground water lies		Same

Total Electrical use =				641,523	kWh/yr				Service boiler plants	Material	$ 15,000
Electrical Cost per kWh =				0.0942	Per kWh				labor - 1 man 4 hrs/day 300 day/yr @ $60/hr		$ 72,000
Total Electrical Cost per yr =				$ 60,431	plus $15,266 =	75,697	dollars		Service steam stations		$ 10,000
Water Cost											
Existing Use	9274	KGAL									
Water use - 25% of existing	2318	KGAL									
						Existing Make-up Use	101	KGAL			
Water Supply Cost	5763	Dollars	2.4857	Dollars/ kgal							
Sewer Cost, 50% of Supply Water flow	9336	Dollars	3.24	Dollars/ kgal							
	15099	Dollars									
Total Water Costs	15,099	Dollars				Chemicals	$6,000		Ref A = Henderson Hall Site Eval. For Miura Boiler I installation		

Fort Meyer — Hot Water with HHHW

2005 Building Heating Use Ref B	14201	MWH/a	48,468	MMBTH
Energy use by Buildings to be Removed - Ref C	2292	MWH/a	7,823	MMBTH
Projected energy Use by remaining bldg	11909	MWH/a	40,645	MMBTH
Building Losses 20 % of Bldg Heat	2382	MWH/a	8,129	MMBTH
DHW Heating Use	1507	MWH/a	5,143	MMBTH
Make-up Water Heating Ref A	1594	MWH/a	5,440	MMBTH
Distribution Losses	5067	MWH/a	17,294	MMBTH
			-	
Total Projected energy Use by Hot Water Sys	22459	MWH/a	76,652	MMBTH
Total Energy Output	76652	Million BTUH		
Total Site Energy Output	98311	Million BTUH		
Total Input Energy 83.5% boiler Efficiency =	119,970	Million BTUH		
Total Energy Input	35151	MWH/a		
Losses Fort Meyer 4-19.xls = Ref A				
Heating Demand Estimates 3-26.xls = Ref B				
Fort Meyer heating demand 060508.xls, 4th tab - Ref C				
	Projected Hot Water System Energy Use			
Fuel Use =		35,151	Million BTUh	
Summer Use =		42%	of time, 5 months	
Distribution =		2595	MWH/a	
Makeup Water		680	MWH/a	
DHW		627	MWH/a	
Total Summer		3902	MWH/a	
Total Summer energy Use in Nat gas		159506	Therms	

Cost/therm =		0.923	Dollars	
Total Winter Use		30477	MWH/a	
Total Winter energy =		104019	Million Btu/yr	
Total Nat Gas	88%	91537	Million Btu/yr	
Total Fuel oil =	12%	12482	Million Btu/yr	
Total Nat Gas		915368	Therms	
Total Fuel oil =		87903	gallons	
Fuel Oil cost =		1.72	Per gallon	
Nat. Gas Cost =		0.49	Per therm	
Summer cost		147,224	Dollars	
Winter Cost		448,530	Dollars	
Total natural Gas Cost		595,754	Dollars	
Fuel Oil Cost		151,194	Dollars	

Electrical									
Return Condensate Pumps									
	Steam Produced =	93,482,000		pounds =	11199144	gal	0.1198	gal per pound	
	Make-up water =	5%	for Blowdown		559957	gal			
	Condensate return water =				10639186	gal or	20.2	gal/min	
	Pump energy At 8.5 gpm & 30 ft head =				0.15	water horsepower average/minute			
	Motor Hp @ 70 % efficiency =				0.22	Motor horsepower average/minute			
	Electrical use =			85,896	kWh/yr		$ 8,091	Per year	
Boiler Feed Pumps									
	Steam Produced =	93,482,000		pounds =	11199144	gal			
	Boiler feed water =				21.3	gal/min			
	Boiler feed water @ 90 psi or 207 feet head								
	Pump energy At 25.9 gpm & 207 ft head =				1.11	water horsepower average/minute			
	Motor Hp @ 70 % efficiency =				1.59	Motor horsepower average/minute			
	Electrical use =			623,880	kWh/yr		$ 58,769	Per year	
Combustion Fans - Boilers					Hrs operating				
				KW use	Winter	Summer	kWh/yr	Total kWh/yr	
	20,000 lb steam boiler - 10 hp fan			7.46	5040		37598		
	10,000 lb steam boiler - 5 hp fan			3.73	2160	3720	21932		
							59,531	kWh/yr	
	Winter Hrs	3 months large & small boilers on			2160	hrs/yr	$ 5,608	Per year	
	Winter Hrs	4 months large boiler on			2880	hrs/yr			
	Summer	5 months small boiler on			3720	hrs/yr			
Hot Water Distribution Pumps	From GEF						15,266	Per year	

Electrical									
Total Electrical use =				769,307	kWh/yr				
Electrical Cost per kWh =				0.0942	Per kWh				
Total Electrical Cost per yr =				$ 72,469	plus $15,266 =		87,735	dollars	
Maintenance Costs									
Repair underground water lies	$ 16,100		1,500,000	1%					
Service steam stations	$ 20,000		1,000,000	2%					
Service boiler plants	$ 22,960								
Existing Use	9274	KGAL							
Water Cost Savings - 25% of existing	2318	KGAL							
Supply Savings	5763	Dollars		2.4857	Dollars/ kgal				
Sewer Cost, 50% of Supply Water flow	9336	Dollars		3.24	Dollars/ kgal				
	15099	Dollars							
Chemical Cost	6000	Dollars							

Henderson Hall

		Average Steam use per year (FY 94 - FY 98) Ref A =		16,830,000	Pounds
		Btu/ lb of steam (steam @ 100 psi, Cond 180F) =		1041	
		Annual Million BTUh Use =		17,520	MMBH
17,520	MMBTH	Make-up water heating (55F to 220 F) @ 3% blowdown		139	MMBH
		Total heating output		17,659	MMBH
		Total Heat input Boiler @ 85% efficient =		20,775	MMBH
139	MMBTH	Annual Therms used		207,752	Therms
4000	MMBTH	Annual cost @ $1.18	per therm =	$ 245,251	
21,659	MMBTH				

Electrical

Return Condensate Pumps							
Steam Produced =	16,830,000		pounds =	2,016,234	gal	0.1198	gal per pound
Make-up water =	5%	for Blowdown		100,812	gal		
Condensate return water =				1,915,422	gal or	3.6	gal/min
Pump energy At 8.5 gpm & 30 ft head =				0.03	water horsepower average/minute		
Motor Hp @ 70 % efficiency =				0.04	Motor horsepower average/minute		
Electrical use =			15,464	kWh/yr		$ 1,457	Per year
Boiler Feed Pumps							
Steam Produced =	16,830,000		pounds =	2016234	gal		
Boiler feed water =				3.8	gal/min		
Boiler feed water @ 90 psi or 207 feet head							
Pump energy At 25.9 gpm & 207 ft head =				0.20	water horsepower average/minute		
Motor Hp @ 70 % efficiency =				0.29	Motor horsepower average/minute		
Electrical use =			112,320	kWh/yr		$ 10,581	Per year
Combustion Fans - Boilers				Hrs operating			

		KW use	Winter	Summer	kWh/yr	Total kWh/yr
2 @3,500 lb steam boiler - 2 hp fan		3	5040		15120	
1 @ 3,500 lb steam boiler - 2 hp fan		1.5		3720	5580	
Winter Hrs	7 months two boilers on		5040	hrs/yr	$ 1,950	Per year
Summer	5 months one boiler on		3720	hrs/yr		
Total Electrical use =		148,484	kWh/yr			
Electrical Cost per kWh =		0.0942	Per kWh			
Total Electrical Cost per yr =		$ 13,987				
Maintenance Costs						
Repair underground water lies			Same			
Service boiler plants	Material		$ 15,000			
labor - 1 man 4 hrs/day 300 day/yr @ $60/hr			$ 72,000			
Service steam stations			$ 10,000			
			$ 97,000			
Existing Make-up Use		101	KGAL			
Supply Savings	$ 251	2.4857	Dollars/ kgal			
Sewer Savings	$ 327	3.24	Dollars/ kgal			
	$ 577					
Chemicals	$5,000					

Ref A = Henderson Hall Site Eval. For Miura Boiler Installation

Existing System with HH Steam

Annual Fuel Use - 2005 Ref A	43,739	MWH/a
Total 2005 Steam Made - Ref A	36367	MWH/a
2005 Building Heating Use Ref B	14201	MWH/a
Building Losses 30 % of Bldg Heat	4260	MWH/a
DHW Heating Use	1507	MWH/a
Make-up Water Heating Ref A	3594	MWH/a
Distribution Losses	12805	MWH/a
Energy use by Buildings to be Removed - Ref C	2292	MWH/a
Waste in the Removed Buildings	688	MWH/a
Projected energy Use by remaining bldg	15482	MWH/a
Total Projected energy Use by Steam System	33387	MWH/a
Total Input Energy 83.5% boiler Efficiency =	40,153	MWH/a
Total Energy Input	137043	Million BTUH

Losses Fort Meyer 4-19.xls = Ref A

Heating Demand Estimates 3-26.xls = Ref B

Fort Meyer heating demand 060508.xls, 4th tab - Ref C

Projected Steam System Energy Use

Fuel Use = 137,043 Million BTUh

Summer Use =		42%	of time, 5 months
Distribution =		5327	MWH/a
Makeup Water		1495	MWH/a
DHW		627	MWH/a
Total Summer		7449	MWH/a
Total Summer energy Use in Nat gas		304463	Therms
Cost/therm =		0.923	Dollars
Total Winter Use		31233	MWH/a
Total Winter energy =		106597	Million Btu/yr
Total Nat Gas	88%	93805	Million Btu/yr
Total Fuel oil =	12%	12792	Million Btu/yr
Total Nat Gas		938050	Therms
Total Fuel oil =		90082	gallons
Fuel Oil cost =		1.72	Per gallon
Nat. Gas Cost =		0.49	Per therm
Summer cost		281,019	Dollars
Winter Cost		459,645	Dollars
Henderson Hall Steam natural gas costs		$ 245,251	
Total natural Gas Cost		985,915	Dollars
Fuel Oil Cost		154,940	Dollars
Total Fuel Cost		1,140,855	Dollars

Estimated Energy Use

Average Steam use per year (FY 94 - FY 98) Ref A =			16,830,000	Pounds
	Btu/ lb of steam (steam @ 100 psi, Cond 180F) =		1041	
Annual Million BTUh Use =			17,520	MMBH
Make-up water heating (55F to 220 F) @ 3% blowdown			139	MMBH
Total heating output			17,659	MMBH
Total Heat input Boiler @ 85% efficient =			20,775	MMBH
Annual Therms used			207,752	Therms
Annual cost @	$1.18	per therm =	$ 245,251	

Electrical

Return Condensate Pumps

Steam Produced = 113766237	1.14E+08	pounds =	13629195	gal	0.1198	gal per pound
Make-up water =			9173000	gal		
Condensate return water =			4456195	gal or	8.5	gal/min
Pump energy At 8.5 gpm & 80 ft head =			0.17			
Motor Hp @ 70 % efficiency =			0.24			
Electrical use =		95,940	kWh/yr		$ 9,038	Per year
Subtotal Electrical Use					$ 10,494	

Boiler Feed Pumps

Steam Produced =	1.14E+08	pounds =	13629195	gal		
Boiler feed water =			25.9	gal/min		
Boiler feed water @ 90 psi or 207 feet head						
Pump energy At 25.9 gpm & 207 ft head =			1.36	water horsepower average/minute		
Motor Hp @ 70 % efficiency =			1.94	Motor horsepower average/minute		
Electrical use =		759,252	kWh/yr		$ 71,522	Per year
Subtotal Electrical Use					$ 82,102	

Combustion Fans - Boilers Hrs operating

				KW use	Winter	Summer	kWh/yr	Total kWh/yr	
	20,000 lb steam boiler - 10 hp fan			7.46	5040		37598		
	10,000 lb steam boiler - 5 hp fan			3.73	2160	3720	21932		
								59,531	
	Winter Hrs	3 months large & small boilers on			2160	hrs/yr		$ 5,608	Per year
	Winter Hrs	4 months large boiler on			2880	hrs/yr			
	Summer	5 months small boiler on			3720	hrs/yr			
	Subtotal Electrical Use						$ 7,558		
Total Electrical use =				1,063,207	kWh/yr				
Electrical Cost per kWh =				0.0942	Per kWh				
Total Electrical Cost per yr =				$ 100,154					
Maintenance Savings			HH Steam		Total costs				
Repair underground water lies	$ 139,907				$139,907				
Service steam stations	$ 48,624		$ 10,000		$ 58,624				
Service boiler plants	$ 22,961		$ 82,000		$104,961				
Water Cost Savings	9173	KGAL							
Supply Savings	22801	Dollars	2.4857	Dollars/ kgal					
Sewer Cost, 50% of Supply Water flow	36938	Dollars	3.24	Dollars/ kgal					
	59739	Dollars							
Total water cost	60,316.69				$ 60,317				
Chemical Cost	18000				$ 18,500				

Electrical

Return Condensate Pumps

Steam Produced =	16,830,000		pounds =	2,016,234	gal	0.1198	gal per pound
Make-up water =	5%	for Blowdown		100,812	gal		
Condensate return water =				1,915,422	gal or	3.6	gal/min
Pump energy At 8.5 gpm & 30 ft head =				0.03	water horsepower average/minute		
Motor Hp @ 70 % efficiency =				0.04	Motor horsepower average/minute		

	Electrical use =		15,464	kWh/yr		$ 1,457	Per year
Boiler Feed Pumps							
	Steam Produced =	16,830,000	pounds =	2016234	gal		
	Boiler feed water =			3.8	gal/min		
	Boiler feed water @ 90 psi or 207 feet head						
	Pump energy At 25.9 gpm & 207 ft head =			0.20	water horsepower average/minute		
	Motor Hp @ 70 % efficiency =			0.29	Motor horsepower average/minute		
	Electrical use =		112,320	kWh/yr		$ 10,581	Per year
Combustion Fans - Boilers				Hrs operating			
			KW use	Winter	Summer	kWh/yr	Total kWh/yr
	2 @3,500 lb steam boiler - 2 hp fan		3	5040		15120	
	1 @ 3,500 lb steam boiler - 2 hp fan		1.5		3720	5580	
						20,700	kWh/yr
	Winter Hrs	7 months two boilers on		5040	hrs/yr	$ 1,950	Per year
	Summer	5 months one boiler on		3720	hrs/yr		
Total Electrical use =			148,484	kWh/yr			

Electrical Cost per kWh =			0.0942	Per kWh
Total Electrical Cost per yr =			$ 13,987	
Maintenance Costs				
Repair underground water lies				Same
Service boiler plants	Material			$ 15,000
labor - 1 man 4 hrs/day 300 day/yr @ $60/hr				$ 72,000
Service steam stations				$ 10,000
				$ 97,000
Henderson Hall Steam System				
Existing Make-up Use	101	KGAL		
Supply Savings	$ 251			
Sewer Savings	$ 327			
	$ 577			
Chemicals	$500			
				$ 357,315
Total Annual Cost =				

Ref A = Henderson Hall Site Eval. For Miura Boiler Installation

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Retrofit Options

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14. ABSTRACT

Many of the buildings on Fort Myer, VA are over 50 years old and are serviced by systems and utilities that have been modified and upgraded over the years. The system distribution and central steam heating system is one such system that is now nearing the end its useful life. This study was undertaken to identify the most cost effective solution to provide heat to the Fort Myer's buildings in the future years, whether to: (1) maintain the existing system, (2) convert to a centralized system using hot water, or (3) convert to a decentralized system. An evaluation of the three alternatives showed that a hot water heating conversion will provide the lowest life cycle cost and allow the most fuel flexibility. Fort Myer also manages installation support for Henderson Hall, an adjacent Marine base. This study analyzed two heating options for Henderson Hall: (1) Connecting Henderson Hall buildings to the new hot water distribution system proposed to serve Fort Myer, or (2) using the existing steam heating plant in Building 28 to heat the five Henderson Hall buildings. A life cycle cost analysis shows that the expansion of the hot water system is the most cost effective choice.

15. SUBJECT TERMS

heat distribution systems	Ft. Myer, VA	retrofit
steam heat distribution	operation and maintenance	life-cycle costs

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